CLAIMS

1. An apparatus for deforming a sheet of material, said apparatus comprising a die portion, an electromagnetic actuator, and a conductive frame, wherein:

said die portion defines a profiled surface;

said electromagnetic actuator is arranged opposite said profiled surface of said die portion; and

said conductive frame is configured to

secure said sheet of material in electrical contact with said conductive frame in a position between said electromagnetic actuator and said profiled die surface,

permit deformation of said sheet of material against said profiled die surface upon activation of said electromagnetic actuator, and

define a return path for eddy currents induced in said sheet of material upon activation of said electromagnetic actuator.

2. An apparatus as claimed in claim 1 wherein said eddy current return path defines a circuit comprising at least a portion of said sheet of material and at least a portion of said conductive frame.

3. An apparatus as claimed in claim 2 wherein respective configurations of said conductive frame and said circuit portion of said sheet of material are such that said circuit portion of said sheet defines the greater per unit length resistance portion of said circuit.

4. An apparatus as claimed in claim 2 wherein said conductive frame is configured such that said conductive frame comprises a majority of said circuit defined by said eddy current return path and said sheet.

5. An apparatus as claimed in claim 2 wherein said sheet of material and said conductive frame are configured such that said eddy current return path and an electrical current path defined by said electromagnetic actuator define opposing current loops in a plurality of cross sections of said apparatus.

6. An apparatus as claimed in claim 5 wherein said eddy current return path and an electrical current path defined by said electromagnetic actuator define opposing current loops in parallel cross sections taken over a majority of said apparatus.

7. An apparatus as claimed in claim 5 wherein said eddy current return path and an electrical current path defined by said electromagnetic actuator define opposing current loops in parallel cross sections taken over a substantial entirety of said apparatus.

8. An apparatus as claimed in claim 2 wherein a cross section of said eddy current return path circuit mirrors a cross section of a electrical current path defined by said electromagnetic actuator.

9. An apparatus as claimed in claim 2 wherein substantial portions of said eddy current return path circuit mirror corresponding portions of an electrical current path defined by said electromagnetic actuator.

10. An apparatus as claimed in claim 1 wherein said conductive frame and said sheet of material define a shell enclosing a substantial portion of said electromagnetic actuator.

11. An apparatus as claimed in claim 10 wherein said eddy current return path defined by said conductive frame and said sheet of material loops through a cross section of said shell oriented generally orthogonal to said sheet of material.

12. An apparatus as claimed in claim 1 wherein said conductive frame and said die portion define sheet engaging portions configured to engage a periphery of said sheet of material there between.

13. An apparatus as claimed in claim 12 wherein said conductive frame and said die portion define sheet engaging portions configured to engage the substantially entire periphery of said sheet of material there between.

14. An apparatus as claimed in claim 12 wherein said conductive frame and said die portion are configured to permit compression of said sheet of material between respective sheet engaging portions of said conductive frame and said die portion.

15. An apparatus as claimed in claim 1 wherein said electromagnetic actuator is configured to heat said sheet of material through induction.

16. An apparatus as claimed in claim 1 wherein said electromagnetic actuator comprises an inductive coil.

17. An apparatus as claimed in claim 16 wherein said inductive coil is configured as a multi-turn substantially helical coil.

18. An apparatus as claimed in claim 1 wherein said apparatus further comprises an actuator controller configured to drive said actuator in an induction heating mode characterized by voltage and current profiles selected to heat said sheet of material through induction.

19. An apparatus as claimed in claim 1 wherein said apparatus further comprises an actuator controller configured to drive said actuator in an electromagnetic forming mode characterized by voltage and current profiles selected to generate a repulsive force between said actuator and said sheet of material of sufficient intensity to deform said sheet against said profiled die surface.

20. An apparatus as claimed in claim 1 wherein said apparatus further comprises an actuator controller configured to:

drive said actuator in an induction heating mode characterized by voltage and current profiles selected to heat said sheet of material through induction; and

drive said actuator in an electromagnetic forming mode following said induction heating mode, wherein said electromagnetic heating mode is characterized by voltage and current profiles selected to generate a repulsive force between said actuator and said sheet of material of sufficient intensity to deform said sheet against said profiled die surface.

21. An apparatus as claimed in claim 20 wherein said voltage and current profiles of said respective induction heating and electromagnetic forming modes are distinct to an extent sufficient to ensure primacy of heating over forming in said induction heating mode and forming over heating in said electromagnetic forming mode.

22. An apparatus as claimed in claim 21 wherein a duration of said induction heating mode is sufficient to raise a temperature of said sheet of material above about one-half of the absolute melting point of said sheet of material.

23. An apparatus as claimed in claim 1 wherein said apparatus further comprises a press configured to impart a compressive force upon said sheet of material secured in a position between said conductive frame and said die portion.

24. An apparatus as claimed in claim 23 wherein said compressive force exceeds a repulsive electromagnetic force generated between said actuator and said sheet upon activation of said actuator.

25. An apparatus as claimed in claim 24 wherein said compressive force exceed said repulsive electromagnetic force by at least one order of magnitude.

26. An apparatus as claimed in claim 24 wherein said compressive force exceeds said repulsive electromagnetic force by an amount sufficient to ensure substantially constant conditions of electrical contact between said sheet of material and said conductive frame as said electromagnetic actuator is cycled from an active to an inactive state.

27. An apparatus for deforming a sheet of material, said apparatus comprising:

a die portion defining a profiled die surface;

an electromagnetic actuator arranged opposite said profiled die surface; and

a conductive frame configured to define a return path for eddy currents induced in a sheet of material secured in a position between said electromagnetic actuator and said profiled die surface upon activation of said electromagnetic actuator, wherein

said eddy current return path and an electrical current path defined by said electromagnetic actuator define opposing current paths in said apparatus,

said conductive frame and said die portion comprise respective sheet engaging portions configured to engage peripheral portions of said sheet of material in a position between said electromagnetic actuator and said profiled die surface, and

said engagement of said peripheral portions of said sheet of material is such that a remaining portion of said sheet of material is substantially free to move in the direction of said profiled die surface in response to a repulsive electromagnetic force between said actuator and said sheet upon activation of said actuator.

28. An apparatus for deforming a sheet of material, said apparatus comprising a die portion, an electromagnetic actuator, and a conductive frame, wherein:

said die portion defines a profiled surface;

said electromagnetic actuator is arranged opposite said profiled surface of said die portion;

said conductive frame is configured to

secure said sheet of material in a position between said electromagnetic actuator and said profiled die surface,

permit deformation of said sheet of material against said profiled die surface upon activation of said electromagnetic actuator, and

define a return path for eddy currents induced in said sheet of material upon activation of said electromagnetic actuator such that said eddy current return path defines a circuit comprising at least a portion of said sheet of material and at least a portion of said conductive frame

said sheet of material and said conductive frame are configured such that said eddy current return path and an electrical current path defined by said electromagnetic actuator define opposing current loops in a plurality of cross sections of said apparatus;

said conductive frame and said die portion define sheet engaging portions configured to engage the substantially entire periphery of said sheet of material there between;

said conductive frame and said die portion are configured to permit compression of said sheet of material between said respective sheet engaging portions of said conductive frame and said die portion;

said apparatus further comprises a press configured to impart a compressive force upon said sheet of material secured in a position between said conductive frame and said die portion; and

said compressive force exceeds said repulsive electromagnetic force by an amount sufficient to ensure substantially constant conditions of electrical contact between said sheet of material and said conductive frame as said electromagnetic actuator is cycled from an active to an inactive state.

29. A method of deforming a sheet of material utilizing an apparatus comprising a die portion, an electromagnetic actuator, and a conductive frame, wherein:

said die portion defines a profiled surface, said electromagnetic actuator is arranged opposite said profiled surface of said die portion, and said conductive frame is configured to secure said sheet of material in electrical contact with said conductive frame in a position between said electromagnetic actuator and said profiled die surface, permit deformation of said sheet of material against said profiled die surface upon activation of said electromagnetic actuator, and define a return path for eddy currents induced in said sheet of material upon activation of said electromagnetic actuator; and

said method comprises the steps of

driving said actuator in an induction heating mode characterized by voltage and current profiles selected to heat said sheet of material through induction; and

drive said actuator in an electromagnetic forming mode following said induction heating mode, wherein said electromagnetic heating mode is characterized by voltage and current profiles selected to generate a repulsive force between said actuator and said sheet of material of sufficient intensity to deform said sheet against said profiled die surface.

30. A method of deforming a sheet of material utilizing an apparatus comprising a die portion, and an electromagnetic actuator, wherein said die portion defines a profiled surface and said electromagnetic actuator is arranged opposite said profiled surface of said die portion, said method comprising the steps of:

driving said actuator in an induction heating mode characterized by voltage and current profiles selected to heat said sheet of material through induction; and

driving said actuator in an electromagnetic forming mode following said induction heating mode, wherein said electromagnetic heating mode is characterized by voltage and

current profiles selected to generate a repulsive force between said actuator and said sheet of material of sufficient intensity to deform said sheet against said profiled die surface.

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